EFFECT OF MOISTURE ON NITROGEN MINERALIZATION IN SOME SASKATCHEWAN SOILS

C.A. Campbell[1], R.J.K. Myers and W. Souster

[1]Research Station
Research Branch, Agriculture Canada
Swift Current, Saskatchewan. S9H 3X2

The ever-increasing cost of N fertilizer dictates the need for more efficient use of this nutrient in the future. This then demands that an accurate assessment be made of the N supply that can be expected from a soil. The latter depends on the soils' innate capacity or potential to supply N, as well as such intensity factors as moisture and temperature. At Swift Current, we have begun a study to determine rates of N mineralization in a representative cross section of Saskatchewan soils as influenced by cultivation, soil moisture and temperature. This paper reports on some of our preliminary findings.

There are many problems associated with estimating the nitrogen supplying power of soils in the laboratory (Robinson 1975). Not the least is the empirical nature of the various methods, which provide relative rather than absolute values for N-supplying power. However, through the work of Stanford and coworkers a less empirical expression has been provided (Campbell 1978). Stanford and Smith (1972) defined soil N mineralization potential, N_o, as the total quantity of soil organic N that is susceptible to mineralization according to first-order kinetics. Another value, k, is defined as the mineralization rate constant. The two values, N_o and k, are therefore thought to be definitive soil characters upon which quantitative estimates of N supplied by soils can be based. The approach is promising since it seems to conform to some of our basic tenets, for example, that nitrogen mineralization is related to an "active" nitrogen fraction and not to the total soil nitrogen. Furthermore, Stanford's procedure has been tested with some success *in situ* (Smith et al. 1977; Herlihy 1979), in short growth periods in the greenhouse (Stanford et al. 1973), and under crop growth in field conditions (Stanford et al. 1977; Oyanedel and Rodrigues 1977).

While on sabbatical in Australia, I attempted to assess Standford's technique using five Australian soils. We found that the Arhenius relationship between k and temperature for five surface soils ($\log k = 6.14 - 2285/T$) was similar to that reported for U.S.A. soils by Stanford et al. (1973), thus indicating that this relationship might be a general one. Even so, we still must determine N_o for each soil and this requires long-term incubation. We are in the process of measuring this parameter for a cross section of Saskatchewan soils; these results will be reported at a later date.

In a second experiment to relate N mineralization to soil moisture, the method used by Stanford and Epstein (1974) for normalizing their results proved unsatisfactory. However, using the same general approach and a slightly different method of normalization of the data gave some interesting results. Thus we have repeated this experiment and analysis on the Saskatchewan soils and will present these results here.

MATERIALS AND METHODS

We collected a coarse, medium and fine textured orthic member of the Brown, Dark Brown, Thin Black and Gray Luvisol great groups and some other soils (Table 1). The 0-15 and 15-30 cm segments of virgin and nearby cropland (cereal, stubble fields) were sampled, air-dried, sieved (< 2 mm) and stored for use in the experiments.

Effect of Moisture

Fifty grams of soil was wetted in erlenmeyer flasks with enough 0.01 M $CaCl_2$ solution to bring the moisture contents to predetermined levels equivalent to approximately -0.1, -0.3, -1.0, -5.0, -15.0 and -40.0 bars suction. The soil and solution were thoroughly mixed with a spatula, the mouth of the flask covered with a double layer of parafilm, two pinholes bored in the parafilm and flasks incubated for 2 weeks at 35°C. There were five replicates, two were sampled immediately after wetting (zero time) and three were incubated. Net N mineralization was calculated as the difference between ($NO_3 + NH_4$-N) after 2 weeks and that at zero time.

The regression between net N mineralized and percent moisture (by weight) was determined for each soil. Similar to the findings of Stanford and Epstein (1974), the regressions were linear between -0.2 and -40 bars for most of the soils. However, the range in slopes ($\Delta N_{min}/\Delta\%$ water) was appreciable. Ideally one would like to obtain relations that are independent of soil type, culture, depth and so on so that calibration need not be repeated in the future for other soils. We therefore tried to obtain a generalized equation by relating y (the N mineralized expressed as a proportion of the maximum rate) to x, the proportional moisture content. Here x is equal to $(W - W_o)/(W_{max} - W_o)$ where W is gravimetric moisture content and subscripts max and o refer to -0.3 and -40 bars, respectively.

RESULTS AND DISCUSSION

Effect of Moisture on N Mineralization

The normalization technique used provided one general linear relationship between relative net N mineralization and relative available moisture content for all surface and subsurface soils (Fig. 1) with $r^2 = 0.90^{**}$ and the regression being $y = 0.036 + 0.97x$. However, there were certain "exceptional" soils (mainly Black, virgin, surface soils) which appeared to behave differently from the others (Table 2). These were fitted by a linear regression of $y = .246 + 0.75x$ with $r^2 = 0.88^{**}$. As seen later they could also be fitted by a second degree polynomial. When we excluded these "exceptional" soils from the general regression

Table 1. Some characteristics of selected Canadian soils used in study

Soil**	Culture depth†	ph	% Org N	% Org C*	Moisture held at suctions (bars)‡ -0.3	-15	-40	-100
Brown								
Hatton SL	V 1	7.2	.13	1.18	11.04	7.68	6.35	5.64
" SL	V 2	7.4	.11	.47	11.39	6.59	5.54	4.86
" SL	S 1	7.0	.09	.74	8.22	4.84	3.95	3.14
" SL	S 2	6.9	.06	.56	7.15	4.26	3.66	3.00
Wood Mountain L	V 1	6.8	.25	2.52	23.49	13.25	11.80	10.56
" " L	V 2	7.2	.21	1.86	20.60	12.49	11.23	10.54
" " L	S 1	6.2	.16	1.49	22.13	9.80	8.52	7.27
" " CL	S 2	6.6	.09	.59	23.40	11.06	9.64	8.35
Sceptre C	V 1	7.6	.15	2.12	31.67	19.17	18.37	15.74
" C	V 2	8.0	.08	.72	30.94	18.95	17.79	16.91
" C	S 1	6.8	.11	1.16	28.22	15.97	15.44	14.14
" C	S 2	7.4	.11	.78	27.54	15.61	13.95	12.86
Dark Brown								
Asquith L	V 1	6.9	.27	2.59	18.44	12.39	10.48	8.16
" SL	V 2	7.9	.15	1.59	15.19	9.05	7.50	5.99
" L	S 1	7.3	.15	1.45	18.36	9.52	7.81	7.14
" L	S 2	7.4	.09	.79	15.78	9.34	7.64	6.96
Elstow CL-L	V 1	6.3	.45	4.88	34.70	22.42	18.81	16.83
" CL-L	V 2	6.9	.22	2.28	26.48	14.98	14.48	13.30
" C	S 1	7.6	.11	1.35	26.83	15.10	14.42	13.57
" CL-L	S 2	7.4	.11	1.28	25.29	13.77	11.90	10.96
Sutherland Hvy C	V 1	7.2	.30	3.26	43.58	27.08	25.05	23.50
" Hvy C	V 2	7.7	.15	1.67	38.69	23.17	21.33	20.67
" C	S 1	7.7	.22	1.98	35.71	20.00	18.50	17.50
" C	S 2	7.9	.15	1.19	33.51	20.66	19.00	17.34
Lethbridge CL	S 1	7.4	.14	1.29	19.1	9.80	7.90	6.90
" CL (Alberta)	S 2	7.3	.14	1.33	21.1	10.40	8.60	7.30
Black (Thin)								
Meota SL-L	V 1	6.6	.30	3.31	22.05	14.67	12.18	10.87
" SL	V 2	6.9	.12	1.37	13.12	8.07	6.30	5.48
" SL	S 1	7.3	.08	.85	11.36	6.08	5.10	4.58
" SL	S 2	7.5	.06	.53	9.71	5.82	4.78	4.17
Blaine Lake CL	V 1	6.3	.35	3.95	31.03	17.89	16.05	15.48
" " CL	V 2	7.1	.15	1.67	25.35	13.93	11.79	10.07
" " SiCL	S 1	6.1	.33	4.01	31.89	18.16	16.66	13.28
" " SiCL	S 2	7.1	.17	1.59	28.36	15.66	13.62	12.95
Keatley SiCL	V 1	6.2	.34	3.81	33.76	21.23	19.00	16.07
" SiC	V 2	7.3	.22	2.54	30.41	18.54	17.00	14.86
" SiC	S 1	6.5	.20	1.92	29.71	16.15	14.30	13.34
" C	S 2	7.4	.11	1.40	29.40	17.05	16.46	15.14

Soil	Culture depth	p.H	% Org N	% Org C	Moisture held at suctions (bars) -0.3	-15	-40	-100
Black (Thick)								
Yorkton CL	V 1	7.0	.61	6.69	37.9	25.6	24.5	22.7
" CL	V 2	7.9	.28	2.87	29.5	18.2	17.5	14.8
" CL	S 1	7.8	.24	2.57	23.4	12.4	11.0	9.3
" CL	S 2	8.0	.17	1.81	22.6	11.4	10.2	8.3
Melfort C	S 1	6.8	.48	5.15	40.8	24.1	24.3	22.9
" C	S 2	6.9	.26	2.97	36.1	21.6	20.5	18.9
Assiniboia C	S 1	7.4	.21	2.37	42.8	23.2	21.5	20.0
" C (Manitoba)	S 2	7.8	.13	1.21	33.8	22.7	22.0	21.2
Gray Luvisol								
Sylvania SL	V 1	5.4	.12	1.49	9.78	6.81	6.00	5.05
" LS	V 2	6.2	.03	.14	4.59	2.31	1.80	1.60
" SL	S 1	6.3	.07	.77	8.71	3.84	2.99	2.56
" SL	S 2	6.6	.03	.32	6.75	2.64	2.13	1.80
Waitville SiL	V 1	7.5	.20	2.80	17.74	6.34	5.02	4.19
" CL	V 2	6.8	.08	.63	23.98	14.62	12.54	10.76
" L	S 1	6.2	.07	.89	26.28	15.38	13.08	11.07
" C	S 2	6.1	.07	.66	22.98	8.16	6.46	5.70
Eldersley CL	V 1	7.7	.33	3.30	23.35	7.77	6.10	5.03
" SiCL	V 2	7.9	.09	.92	23.74	13.23	11.45	10.15
" SiL	S 1	7.1	.16	1.92	30.54	14.63	12.76	11.41
" SiCL	S 2	7.0	.06	.41	25.09	13.16	11.80	10.37
Dark Gray								
Tisdale SiCL	V 1	6.3	.52	5.49	36.2	21.8	20.6	19.3
" SiC	V 2	5.8	.14	2.12	27.1	14.9	13.5	10.9
" SiCL	S 1	6.4	.27	2.91	29.2	15.9	14.4	13.9
" C	S 2	6.0	.10	1.01	33.3	19.9	17.6	17.1
Humic Gleysol								
Weyburn CL	V 1	6.9	.69	2.92	51.8	27.2	26.5	24.5
" CL	V 2	7.6	.34	2.37	36.2	18.7	17.0	16.2

† V = virgin; S = cereal stubble; 1 = 0-15 cm; 2 = 15-30 cm

‡ Determined on pressure plate and pressure membrane

* Dry combustion C - Inorganic C

** All soils except those otherwise designated are Saskatchewan soils

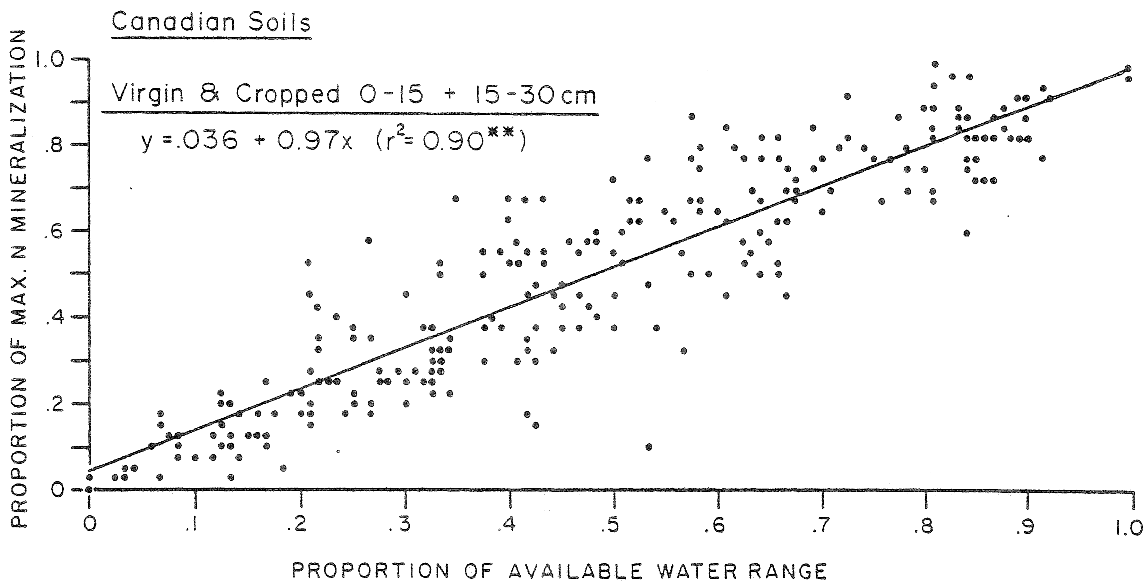

Fig. 1. Relative N mineralization in relation to soil water content expressed as a proportion of the available water range

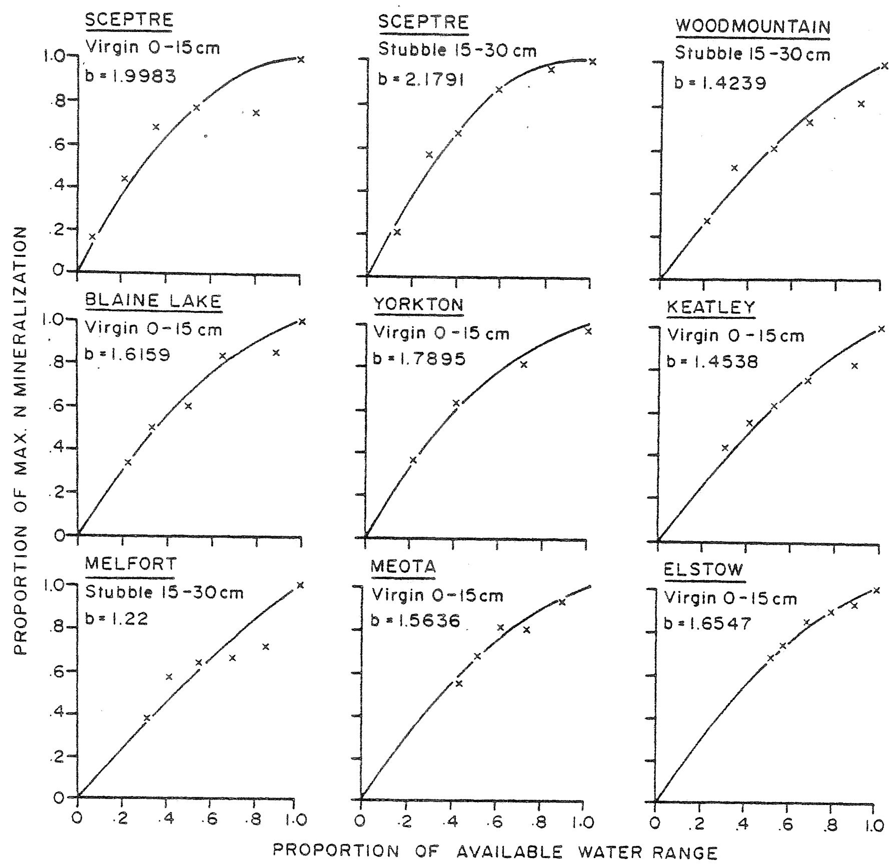

Fig. 2. Relative N mineralization in relation to soil water content expressed as a proportion of the available water range for nine soils giving curvilinear response

we obtained the expression y = .01 + 0.99x for the remaining soils. The latter equation indicates that net N mineralization increases linearly and directly with "available" moisture, and that there is no net mineralization when the "available" water is zero.

Table 2. Relationship between normalized N_{min} (y) and normalized available water (x)† for some Saskatchewan soils

Sample	Depth cm	n	Equation	r^2	S.E. Y-Int.	S.E. x
All soils	0-15 15-30	312	y = 0.036 + 0.97x	0.90**	.011	0.02
All soils other than exceptions	0-15 15-30	260	y = 0.01 + 0.99x	0.92**	.011	0.02
*Exceptional soils	0-15 15-30	52	y = 0.246 + 0.75x	0.88**	.027	0.04

* Soils = Yorkton, Keatley, Blaine Lake, Meota, Elstow and Sceptre virgin 0-15; Melfort, Sceptre and Wood Mountain stubble 15-30 cm.

† $x = \dfrac{\text{(actual gravimetric M.C. = -40 bar M.C.)}}{\cong 0.2 \text{ bar M.C.} - -40 \text{ bar M.C.}}$

$y = [N_{min}/(N_{min} \text{ at } \cong 0.2 \text{ bar}]$

All nine "exceptional" soils showed a curvilinear response, thus we analyzed these using a polynomial model. The equation used was:

$$y = bx + (1 - b)x^2 \tag{1}$$

where the coefficient b is a measure of the degree of curvature. This equation was fitted to all the data so that the regression was constrained to pass through x_0y_0 and x_1y_1 when both axes were scaled between 0 and 1. The results for the exceptional soils (Fig. 2) fitted the data well. Note that the equation gives y = x when b = 1. Thus, if we set b = 1 for all soils where the response was linear then this model fits all of the available data.

Our data show that most of the soils studied could be described by a linear equation. Required inputs to such an equation are -0.3 and -40 bar moisture potentials and the rate of mineralization at optimum moisture content. For the "exceptional" soils we need to determine what character or characteristics can be used to identify them and whether such character(s) can be quantified and used in the equation.

REFERENCES

Campbell, C.A. 1978. Soil organic carbon nitrogen and fertility. In Soil Organic Matter. Developments in Soil Science I. Eds. M. Schnitzer and S.U. Khan, pp. 173-272. Elsevier Scientific Publishing Co., Amsterdam, The Netherlands.

Herlihy, M. 1979. Nitrogen mineralization in soils of varying texture, moisture and organic matter. 1. Potential and experimental values in fallow soils. Plant Soil 53: 255-267.

Oyanedel, C. and Rodriquez, J. 1977. Estimation of N mineralization in soils. Ciencia E. Investigacion Agraria 4: 33-44.

Robinson, J.B.D. 1975. The soil nitrogen index and its calibration with crop performance to improve fertilizer efficiency on arable soils. Special Publication No. 1., Commonwealth Bureau of Soils, Commonwealth Agric. Bureaux, England, 55 pp.

Smith, S.J., Young, L.B. and Miller, G.E. 1977. Evaluation of soil nitrogen mineralization potentials under modified field conditions. Soil Sci. Soc. Am. J. 41: 74-76.

Stanford, G. and Smith, S.J. 1972. Nitrogen mineralisation potentials of soils. Soil Sci. Soc. Am. Proc. 36: 465-472.

Stanford, G., Frere, M.H. and Schwaninger, D.H. 1973. Temperature coefficient of soil nitrogen mineralisation. Soil Sci. 115: 321-323.

Stanford, G. and Epstein, E. 1974. Nitrogen mineralization - water relations in soils. Soil Sci. Soc. Amer. Proc. 38: 103-107.

Stanford, G., Cartner, J.N., Westermann, D.T. and Meisinger, J.J. 1977. Residual nitrate and mineralisable soil nitrogen in relation to nitrogen uptake by irrigated sugarbeets. Agron. J. 69: 303-308.